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Technical Memorandum

To:	Kathy Arnold	**From:**	Ronson Chee, Ph.D, P.E.
Company:	Rosemont Copper Company	**Date:**	July 14, 2017
Re:	Rosemont Stock Ponds – Preliminary Potential Runoff Volumes Calculation	**Doc #:**	133-24549-17008-01
CC:		**Reviewed by:**	Michael Zeller, P.E., P.H.

1.0 Introduction

This Technical Memorandum discusses preliminary hydrologic calculations performed to estimate "average-annual" surface water runoff volumes that may potentially report to 21 stock ponds located in the Rosemont Project watershed and in an adjacent portion of the Davidson Canyon watershed (see Figure 1). The Rosemont Project watershed is defined herein as the watershed upstream of USGS streamgage 09484580 (USGS streamgage) located at the intersection of Barrel Canyon and State Route 83. The calculations performed herein are primarily intended to provide a relative comparison to the previously estimated "annual-average" runoff volume of 1,404 ac-ft computed at the USGS streamgage, as discussed in the Technical Memorandum titled *Baseline & Post Mine Hydrology and Sediment Delivery at USGS Gage for Barrel Alternative* dated July 11, 2012 (Tetra Tech, 2012). Accordingly, the same hydrologic runoff regression methodology used in Tetra Tech (2012) was implemented here to estimate potential "average-annual" runoff volumes reporting to stock ponds. The potential "average-annual" runoff volumes reporting to stock ponds as presented in this Technical Memorandum should only be used as a comparative analysis to results presented in Tetra Tech (2012).

It also should be noted that runoff data collected from 2009 to the present at the USGS streamgage has produced an eight-year "average-annual" runoff of approximately 118 acre-feet (USGS, 2017). The measured annual runoff values at the USGS streamgage are significantly lower, by a factor of about 10, than the annual runoff values predicted by the regression methodology used here and in Tetra Tech (2012). This demonstrates the very conservative nature of the methodology implemented here.

Lastly, the storage capacity of stock ponds was not considered in this analysis. Only potential "average-annual" runoff volumes that report to each stock pond were calculated. Whether the stock ponds can actually retain the calculated runoff values on a yearly basis was not considered. Therefore, loss factors such as infiltration, evaporation, and plant transpiration that occur at stock ponds, thus further decreasing the downstream quantity of annual runoff, were also not considered.

2.0 Technical Approach

In order to remain consistent with the previous hydrologic methodology, the "average-annual" runoff values were estimated using the two regression relationships as discussed in Tetra Tech (2012) and are re-presented here in Equations 1 and 2. The "average-annual" runoff volume estimate of 1,404 ac-ft computed at the USGS streamgage per Tetra Tech (2012) is the average of the two values as calculated by the two regression relationships in Equations 1 and 2. The validity of this method (averaging the two values) to estimate "average-annual" runoff volumes reporting to stock ponds was re-evaluated and amended as discussed in the Section 3.0. Both regression methods are presented here for thoroughness and clarity.

The first regression relationship is the Seasonal Mean-Discharge Equation per Moosburner (1970) and is shown here as Equation 1:

$$Q_{AA} = 1.31849 A^{0.71} PS^{2.25} \qquad \text{Eq. 1}$$

Where,

Q_{AA} = Average-annual runoff, in acre-feet;

A = Watershed area, in square miles; and

PS = Seasonal precipitation, in inches (0.51 of total annual precipitation).

The second regression relationship is the multi-variable relationship developed by Tetra Tech and is shown here as Equation 2:

$$Q_{AA} = 8.44885 \times 10^{-6} A^{0.9821} P^{2.1198} E^{1.2101} \qquad \text{Eq. 2}$$

Where,

Q_{AA} = Average-annual runoff, in acre-feet;

A = Watershed area, in square miles;

P = Average-annual precipitation, in inches (18 inches); and

E = Mean watershed elevation, in feet.

The derivation of inputs into the regression equations are explained in the following sections.

2.1 Watershed Area

For stock ponds located in the Rosemont Project watershed, a combination of 2-foot and 10-foot topographic data in AutoCAD format were used to delineate and estimate watershed areas (*A*). Similarly, for stock ponds in the adjacent Davidson Canyon watershed, USGS topographic quad maps and aerial imagery in ArcGIS format were used to estimate watershed areas (*A*). It is important to note that watershed delineations for stock ponds in the Davidson Canyon watershed were estimated to the most practical extent using ArcGIS. Because of the low resolution of USGS topographic quad maps and aerial imagery in relation to the small watershed areas, higher resolution topographic maps and/or field verifications are needed to improve the accuracy of watershed delineations. Because of the preliminary nature of the calculations, more accurate delineations may be more appropriate at the next study level.

2.2 Watershed Average-Annual Precipitation and Elevation

In order to keep the methodology consistent with the previous estimates as calculated in Tetra Tech (2012), the average-annual precipitation was assumed to be 18 inches and the mean watershed elevation (*E*) was assumed to be 5,000 feet for all watersheds reporting to stock ponds. This was deemed appropriate, as the mean elevations of watersheds reporting to the stock ponds were close to the original elevation of 5,000 feet that was assumed for the Rosemont Project watershed in Tetra Tech (2012). The actual mean elevations for watersheds reporting to stock ponds considered in this analysis ranged from 4,420 feet to 5,550 feet and had an arithmetic average of 5,022 feet. The effects of elevation on average-annual precipitation may be more closely evaluated and implemented at the next study level. However, the effects of elevation on rainfall are not expected to significantly alter the results presented here.

3.0 Results

3.1 Potential average-annual runoff volumes reporting to stock ponds

The estimated "average-annual" runoff volumes reporting to each stock pond using Equations 1 and 2, as well as their combined average are provided in Table 1. In Table 1, stock ponds are categorized based on their location relative to the Rosemont Project watershed and anticipated project mining activities. Stock ponds located within the Rosemont Project watershed are categorized as "on-site" and stock ponds located outside the Rosemont Project watershed are categorized as "off-site." Furthermore, "on-site" stock ponds are subdivided into "captured" and "not captured." Stock ponds that will ultimately be impacted by mining activities are termed "captured" while nonimpacted stock ponds are termed "not captured."

The results in Table 1 demonstrate that the "average-annual" runoff volumes as estimated by Equation 1 are roughly 240% higher than runoff volumes as estimated by Equation 2. This is significantly different than the results presented in Tetra Tech (2012) where the "average-annual" runoff volume as estimated by Equation 1 was about 19% lower than the runoff volume as estimated by Equation 2. This dichotomy is most likely due to the size of the watersheds under consideration compared to the size of the watersheds from which the regression relationship in Equation 1 was derived. Equation 1 was derived from significantly larger watersheds that yield much larger average "average-annual" runoff values. This creates a bias that most likely overestimates runoff for much smaller watersheds. In Tetra Tech (2012), Equation 1 was used to estimate runoff for the Rosemont Project watershed which has area of 14 sq. mi., whereas the areas reporting to stock ponds in this analysis are primarily under one (1) sq. mi. (the largest watershed area is 1.147 sq. mi. which reports to Barrel Canyon East Dam Tank).

Because of the very high runoff estimates generated by Equation 1 it was not deemed appropriate to use the average of the two values generated by Equations 1 and 2 as was previously calculated in Tetra Tech (2012). Instead, the results generated by Equation 2 alone were deemed the most reasonable and should be used to estimate "average-annual" runoff volumes reporting to stock ponds.

The sole use of Equation 2 to estimate the "average-annual" runoff volume reporting to stock ponds can be validated by considering a qualitative analysis based entirely on watershed area. For example, the combined watershed areas reporting to on-site stock ponds (approximately 2.375 sq. mi.) is approximately 17% of the Rosemont Project watershed area (i.e., 2.375 sq. mi. ÷ 14 sq. mi.). Using Equation 2, the estimated runoff volume reporting to the on-site stock ponds is 279.9 ac-ft (see Table 1). This runoff volume is approximately 20% of the runoff volume previously estimated at the USGS gage (i.e., 279.9 ac-ft ÷1,404 ac-ft), which is in close agreement with the contributing area percentage of 17%. Using Equation 1, the estimated runoff volume reporting to the on-site stock ponds is 632.1 ac-ft (see Table 1). This runoff volume is approximately 45% of the runoff volume previously estimated at the USGS gage (i.e., 632.1 ac-ft ÷1,404 ac-ft). This is greater than the contributing area percentage of 17% by a factor of 2.6 which is not reasonable estimate from a hydrological perspective.

Table 1. Estimated Average-Annual runoff volumes reporting to stock ponds

Stock Tank Name/ID	Contributing Watershed Area (sq. mi.)	Annual Runoff Volume per Eq. 1 (ac-ft)	Annual Runoff Volume per Eq. 2 (ac-ft)	Avg. of Eq. 1 & Eq. 2 (ac-ft)
On-site (Captured)				
Trail Creek Upper Stock Tank	0.127	44.6	**15.2**	29.9
Barrel Canyon East Dam Tank	1.147	213.2	**132.5**	172.8
Barrel Tank	0.127	44.7	**15.3**	30.0
North Basin Tank	0.144	48.9	**17.3**	33.1
Rosemont Spring Stock Tank	0.111	40.7	**13.4**	27.1
Wasp Canyon Stock Tank 2	0.076	31.1	**9.2**	20.2
Asarco Stock Tank	0.177	56.5	**21.1**	38.8
*Upper Stock Tank/Lower Stock Tank 1/Lower Stock Tank 2	0.133	46.3	**16.0**	31.2
Wasp Canyon Stock Tank	0.002	2.7	**0.3**	1.5
subtotal	*2.045*	*528.6*	***240.4***	*384.5*
On-site (Not Captured)				
Gunsight Pass Tank	0.008	6.3	**1.0**	3.6
McCleary Canyon Stock Tank	0.290	80.2	**34.3**	57.3
Rosemont Crest Tank	0.032	17.0	**4.0**	10.5
subtotal	*0.330*	*103.5*	***39.3***	*71.4*
Off-site				
Adobe Tank (ES-6)	0.346	91.1	**40.9**	66.0
ES-7	0.048	22.5	**5.9**	14.2
ES-1	0.017	10.9	**2.2**	6.5
Big Pond (ES-2)	0.197	61.1	**23.5**	42.3
ES-3	0.060	26.1	**7.3**	16.7
ES-4	0.121	43.3	**14.6**	28.9
**Questa Spring Stock Tank	0.000	0.0	**0.0**	0.0
subtotal	*0.790*	*225.0*	***94.3***	*174.6*
Grand Total	*3.165*	*887.0*	***374.1***	*630.5*

Note: Values shown in table may not add correctly to totals due to rounding precision.

*Upper Stock Tank, Lower Stock Tank 1 and Lower Stock Tank 2 are a series of cascading ponds , therefore only one watershed area was delineated.

**Questa Spring Stock Tank is only a concrete box, no watershed was delineated.

4.0 Conclusion

"Average-annual" surface stormwater runoff volumes that may potentially report to stock ponds located in the Rosemont Project watershed and in the adjacent Davidson Canyon watershed have been estimated using two previous runoff regression methodologies from Tetra Tech (2012). Previous runoff estimates computed at the USGS streamgage consisted of averaging two values from two different runoff regression methodologies as presented in Equations 1 and 2. The application of both equations here demonstrated that use of Equation 1 yielded approximately 887.0 ac-ft of "average-annual" runoff that reports to stock ponds. This is a significant overestimate and is due primarily to the small size of the watersheds under consideration in comparison to the significantly larger watershed areas used to develop the regression relationship. Accordingly, Equation 1 should not be used while Equation 2 alone should be used for estimating "average-annual" runoff volumes reporting to stock ponds. Equation 2 alone yielded a more reasonable estimate of approximately 374.1 ac-ft of "average-annual" runoff reporting to stock ponds. The estimates generated by Equation 2 alone were deemed more reasonable than the previous averaging method because the percentage of runoff volume reporting to stock ponds in relation to the previous runoff volume estimate for the Rosemont Project watershed was close in value to the percentage of the watershed area reporting to stock ponds in relation to the Rosemont Project watershed area. Lastly, the values as calculated by Equation 2 should only be used for comparative purposes to the previously estimated runoff volume of 1,404 ac-ft as computed at the USGS streamgage in Tetra Tech (2012).

REFERENCES

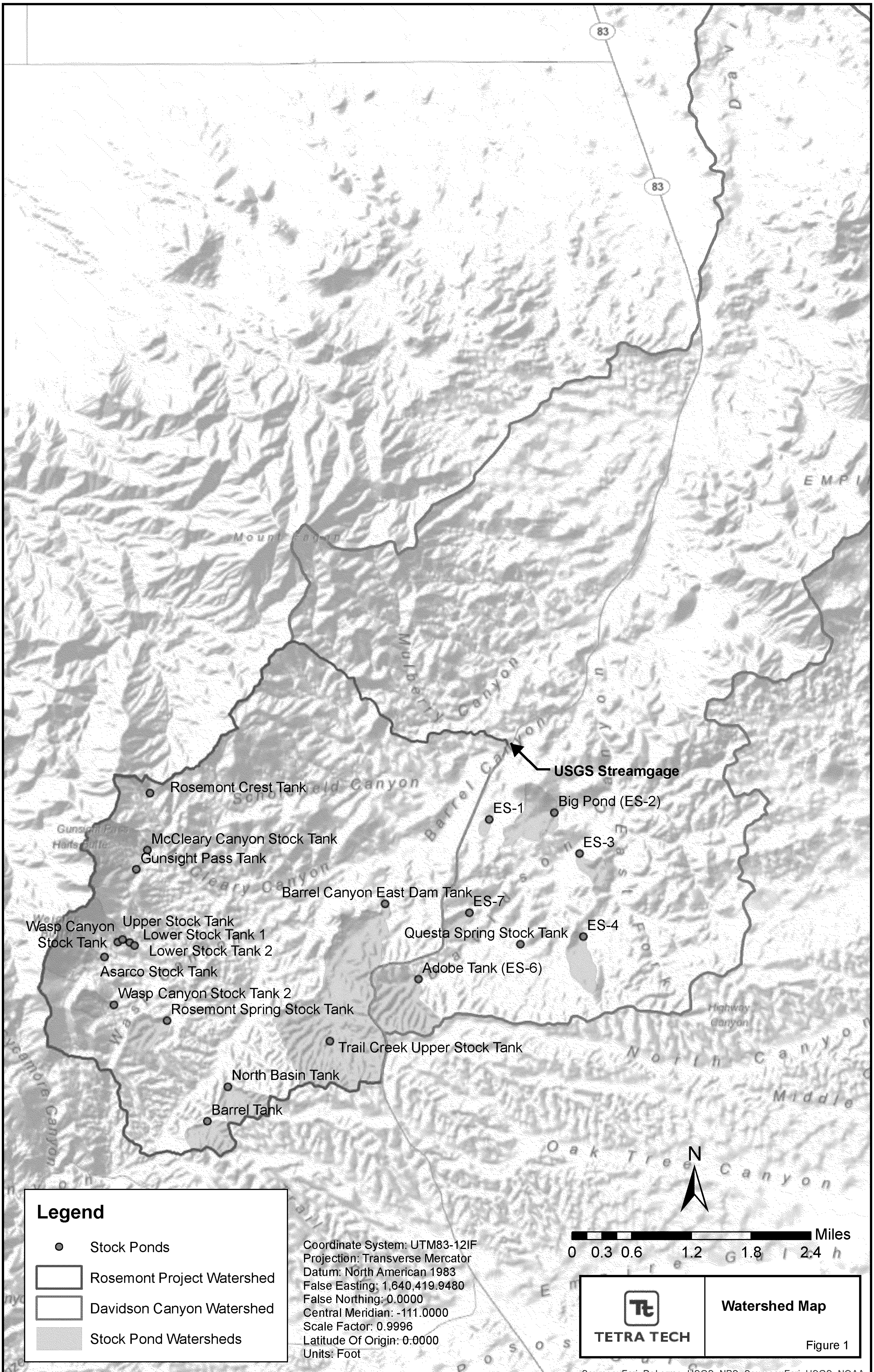
Moosburner, Otto (1970). *A Proposed Streamflow-Data Program for Arizona*. United States Geological Survey (USGS) Open-File Report 70-231. Dated August 1970.

Tetra Tech (2012). *Baseline & Post Mine Hydrology and Sediment Delivery at USGS Gage for Barrel Alternative*. Technical Memorandum dated July 11, 2012.

United States Geological Survey (USGS) (2017). *USGS National Water Information System: Web Interface*. https://waterdata.usgs.gov/az/nwis/uv?site_no=09484580. Website accessed June 29, 2017.

Western Regional Climate Center (WRRC) Cooperative Extension (COOP) (2015). *Climate data*. http://www.wrcc.dri.edu/summary/Climsmaz.html. Website accessed April 4, 2017.

FIGURE



USGS Streamgage
Rosemont Crest Tank
McCleary Canyon Stock Tank
Gunsight Pass Tank
Barrel Canyon East Dam Tank
Wasp Canyon Stock Tank
Upper Stock Tank
Lower Stock Tank 1
Lower Stock Tank 2
Asarco Stock Tank
Wasp Canyon Stock Tank 2
Rosemont Spring Stock Tank
Trail Creek Upper Stock Tank
North Basin Tank
Barrel Tank
ES-1
Big Pond (ES-2)
ES-3
ES-7
Questa Spring Stock Tank
ES-4
Adobe Tank (ES-6)
Mulberry Canyon
Barrel Canyon
North Canyon
Oak Tree Canyon
Sycamore Canyon
Mount Fagan
83
N
Miles
0 0.3 0.6 1.2 1.8 2.4
Legend
Stock Ponds
Rosemont Project Watershed
Davidson Canyon Watershed
Stock Pond Watersheds
Coordinate System: UTM83-12IF
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 1,640,419.9480
False Northing: 0.0000
Central Meridian: -111.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Foot
TETRA TECH
Watershed Map
Figure 1
Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA